

Interpretation of CMS searches for beyond-
standard-model phenomena in the
SuperSymmetry framework with simplified
models

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On behalf of the CMS collaboration

SUSY11, Fermilab, 27august - 2sept

Introduction

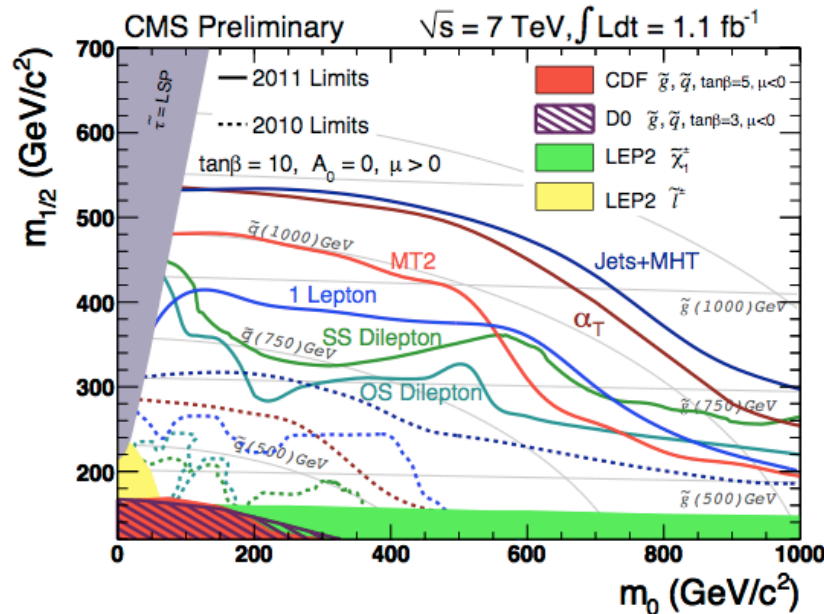
- Many searches for new physics have been already done or are in the works by the CMS experiment.
- No significant excesses above the Standard Model prediction have been observed so far in the data.
- In this talk, we distinguish between the *experimental results*, which are model independent and their *interpretation*. This distinction is important because the same experimental results can be interpreted in different ways.

SUSY limits in CMSSM

Historically, the SUSY search groups have focused on CMSSM and GMSB models. Many benchmark points have been identified to cover many possibilities.

SUSY limits in CMSSM

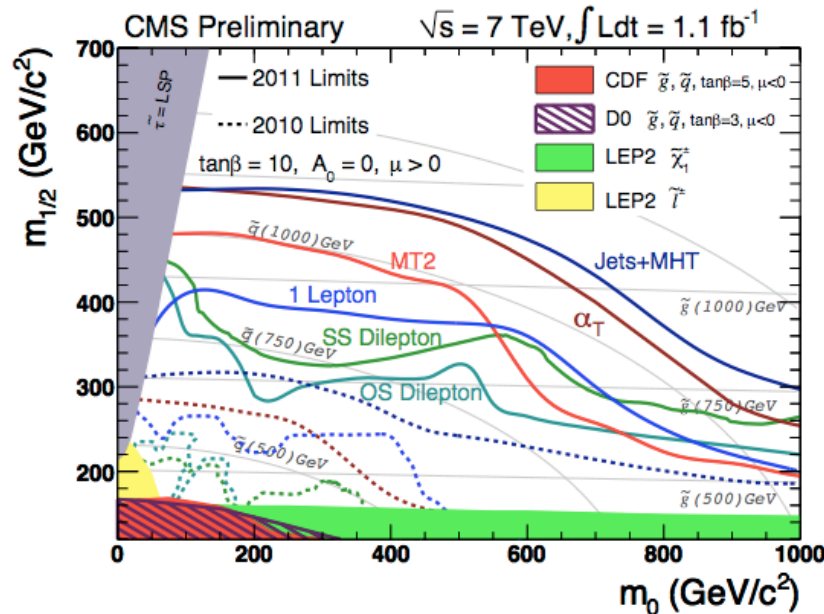
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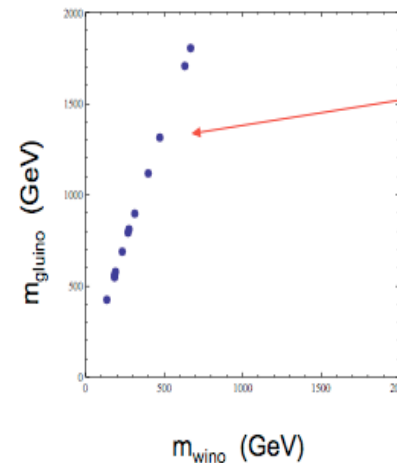
But the CMSSM approach offers only a limited spectrum of mass splittings, and many production and decay channels contribute to each benchmark point in a model-dependent way.

SUSY limits in CMSSM

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CMS SUSY TDR benchmarks



Stretched Gauge Ordered Spectra

Relatively Low σ

Led to Expectation that Need $O(100's) \text{ pb}^{-1}$ to go Beyond Tevatron

(Gaugino Unification)

CMSSM is not completely representative of SUSY ... and a long list of models can be added like GMSB/SplitSusy

Complementary approach

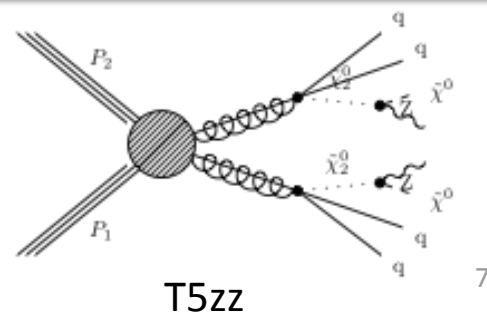
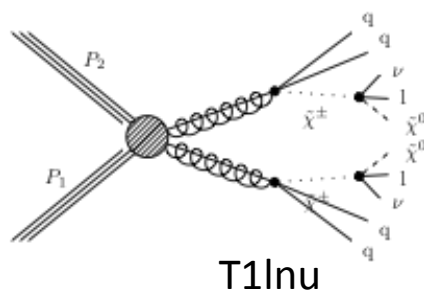
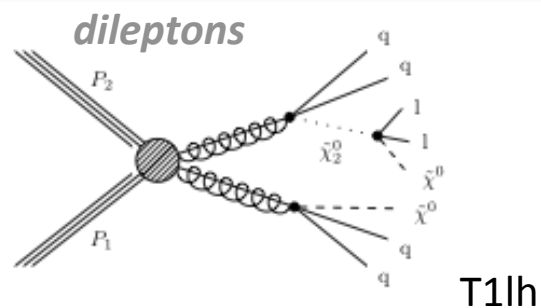
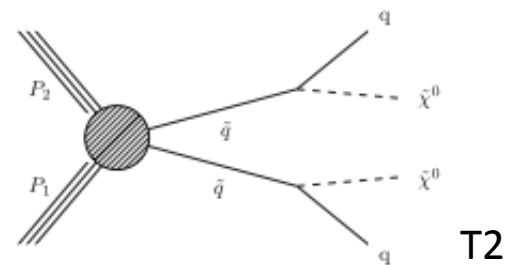
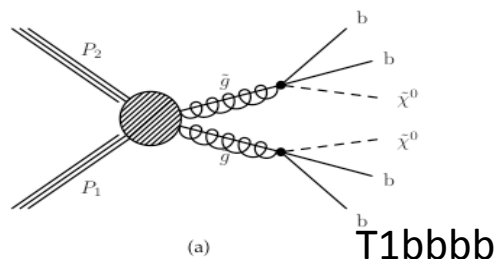
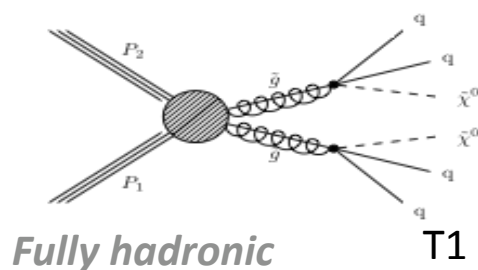
- In addition to the traditional approach using constrained models, it is useful to pursue more flexible interpretations of CMS results. Upper limits on the cross-sections times branching ratios ($\sigma \times \text{BR}$) for new physics based on the simplified models are obtained.
- In a simplified model a limited set of hypothetical particles and decay chains are introduced to produce a given topological signature. The main free parameters are masses and branching ratios.
- The CMS simplified models were chosen to cover a large volume of the kinematic phase space of all considered final states. Limits are presented exclusively for each topology.

Topologies under study

In the following, we discuss the few topologies that are both distinguishable and salient for a few CMS analyses.

Assumptions:

- Presence of missing transverse energy from stable weakly interacting massive particle (LSP).
- The new particles are strongly produced in pairs.



Outline of the results

The results are presented in terms of **signal efficiency** and **cross section x BR upper limit**.

- When more than one selection region is defined for an analysis the minimum of the measured cross section limit is taken.
- As reference, these cross sections calculated with Prospino will be used to draw the 95% exclusion contours on the cross section times branching fraction.

Provides a well-defined reference to compare to specific new models. Also provides insight into the effects of kinematic extremes on our analyses.

The results are shown as function of the masses of the particles involved.

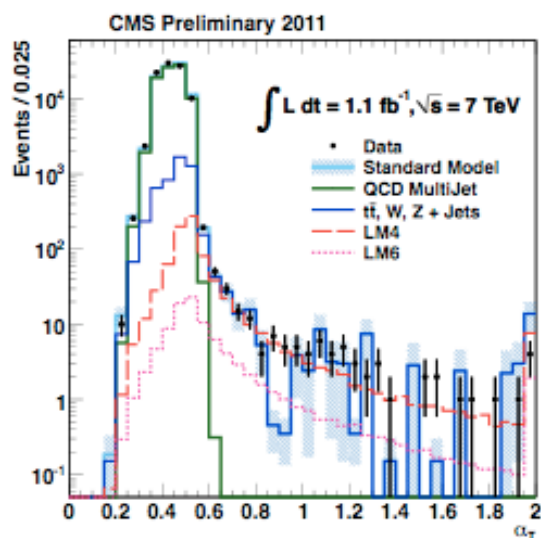
- especially important is the region when the selection thresholds occur at the tails of the distributions.
- a cut on small $\Delta M(\text{gluino}, \text{LSP})$ and gluino mass is needed to remove sensitivity to statistical errors and signal modeling.

Limit from α_T analysis

CMS-PAS-SUS-11-003

$$\alpha_T = \frac{E_T^{\text{jet}_2}}{M_T} = \frac{E_T^{\text{jet}_2}}{\sqrt{\left(\sum_{i=1}^2 E_T^{\text{jet}_i}\right)^2 - \left(\sum_{i=1}^2 p_x^{\text{jet}_i}\right)^2 - \left(\sum_{i=1}^2 p_y^{\text{jet}_i}\right)^2}}$$

Rather than defining a specific signal region, this analysis searches for an excess of events in data over the Standard Model (SM) expectation in a range of exclusive bins of HT . This is done to makes the search optimization less dependent on the (unknown) energy scale of a new physics signal.

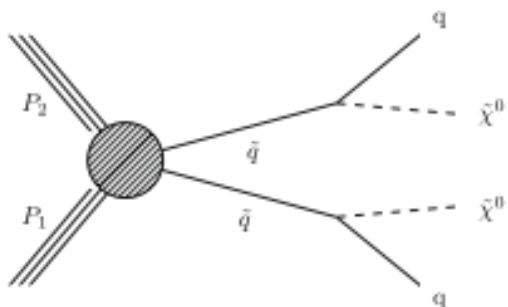


LM4: $M(\text{gluino}) \sim 690 \text{ GeV}$ $M(\text{squark}) \sim 650 \text{ GeV}$

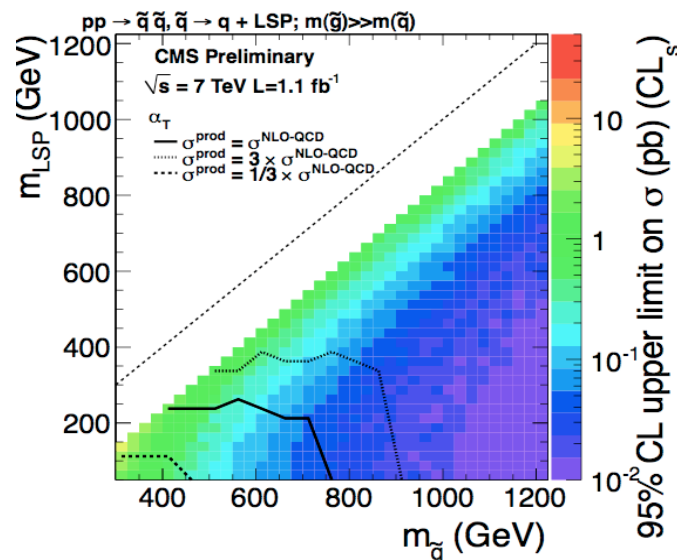
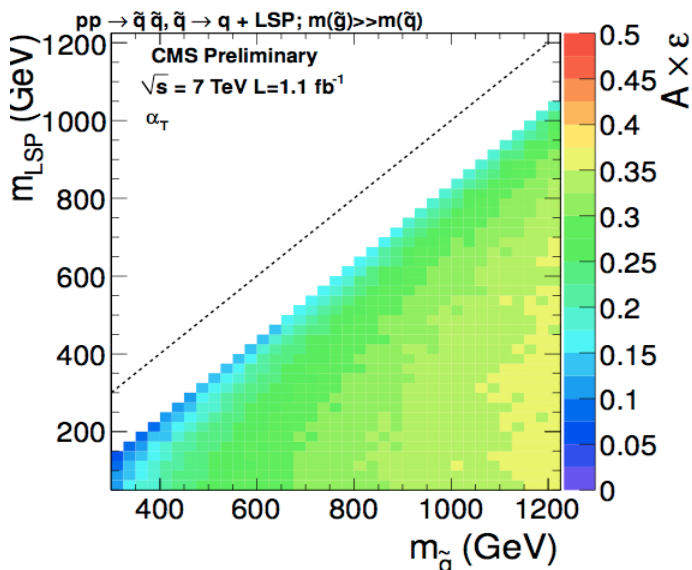
LM6: $M(\text{gluino}) \sim 930 \text{ GeV}$ $M(\text{squark}) \sim 840 \text{ GeV}$

Limit on T2 topology from α_T analysis

CMS-PAS-SUS-11-003

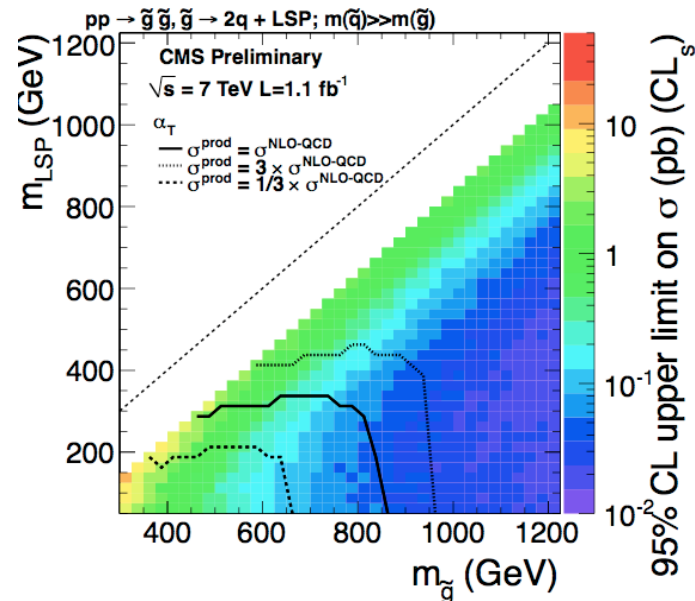
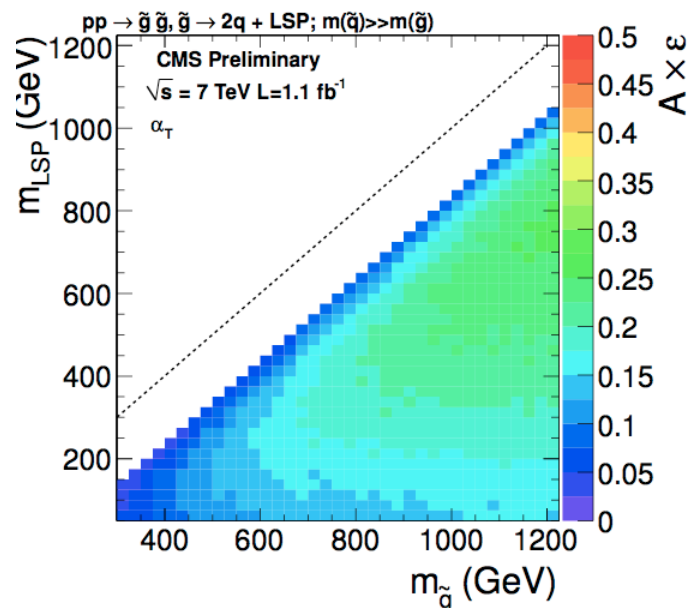
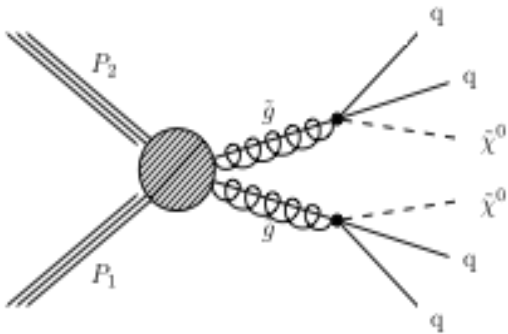


- Low efficiency in the low squark-LSP mass splitting translates into a low cross section upper limit.
- At high squark mass, higher selection efficiency compensated by lower cross section.
- For compressed spectra, results in a poor limit as well.



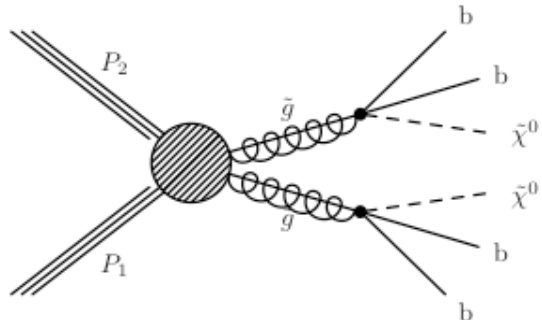
Limit on T1 topology from α_T analysis

CMS-PAS-SUS-11-003



Limit on T1bbbb topology from MT2 analysis

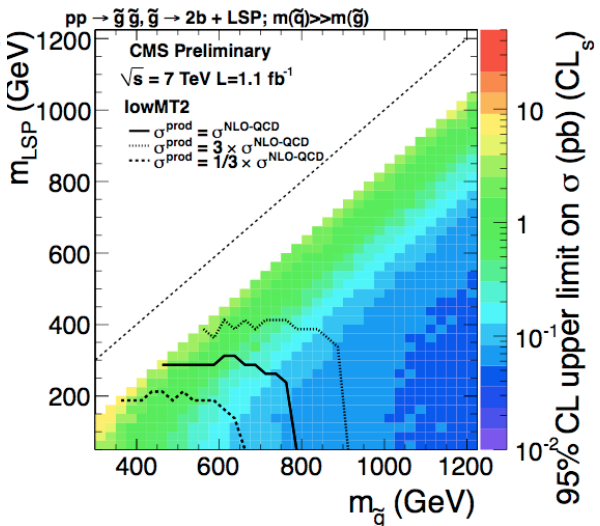
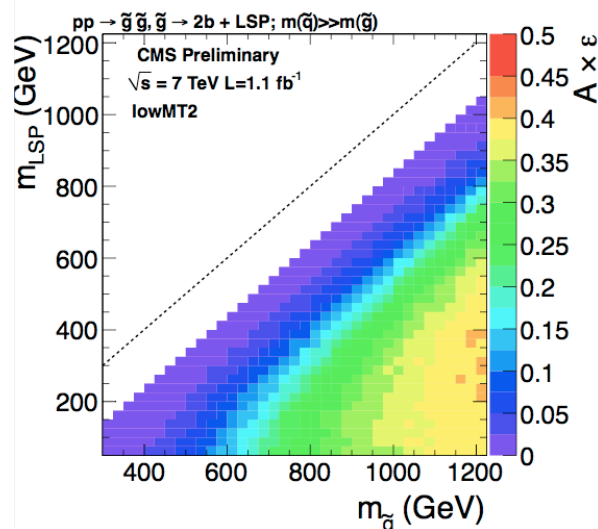
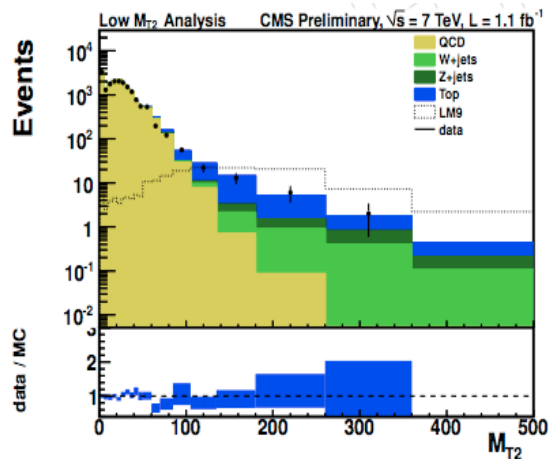
CMS-PAS-SUS-11-005



This topology look at the role of the 3rd generation.

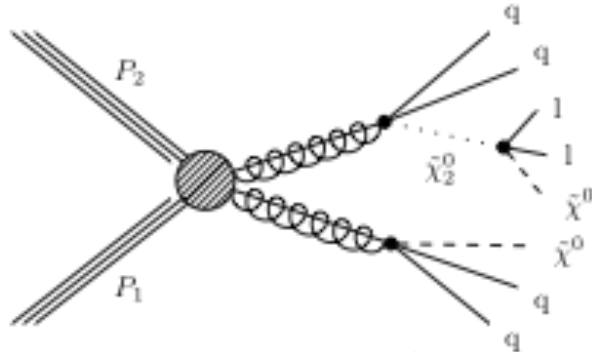
This analysis uses the MT2 observable to suppress the background and requires at least one jet in the final state to be identified as b.

$$(M_{T2})^2 = 2A_T = 2p_T^{vis(1)} p_T^{vis(2)} (1 + \cos\phi_{12}),$$



Limit on T1Lh topology from opposite-sign dilepton analysis

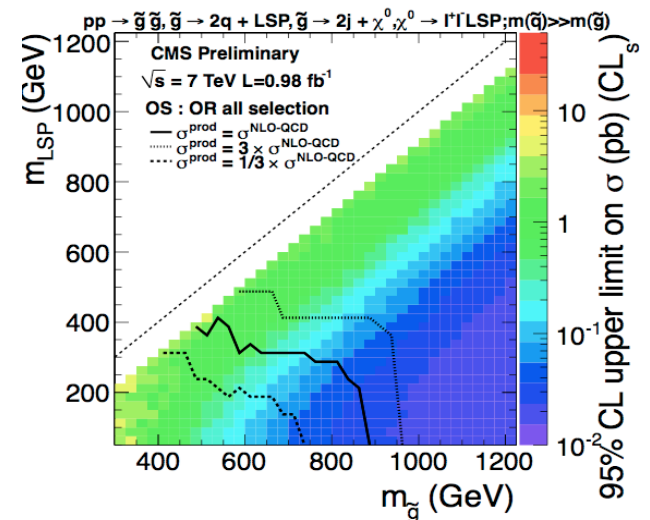
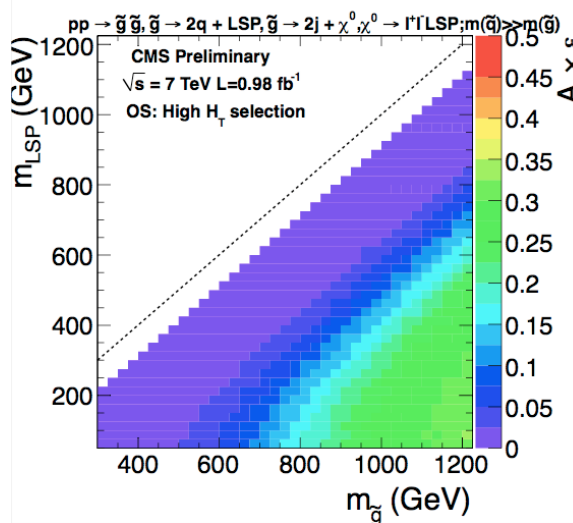
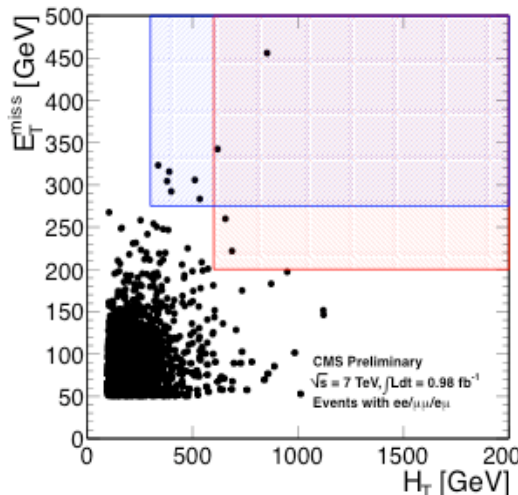
CMS-PAS-SUS-11-011



In this topology the neutralino is forced to decay in a 3 body final state.

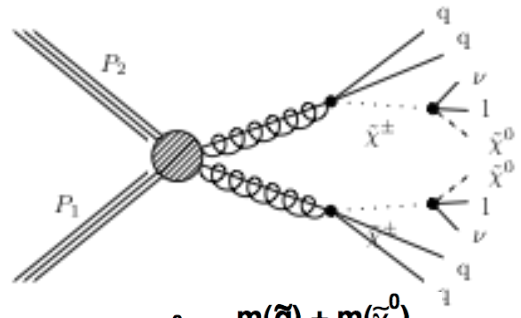
We search for an excess of events with opposite flavor or same flavor and outside the Z mass window accompanied by large MET and HT.

$$m(\tilde{\chi}^\pm, \tilde{\chi}_2^0) = \frac{m(\tilde{g}) + m(\tilde{\chi}^0)}{2}$$



Limit on T1nu topology from same-sign (SS) dilepton analysis

CMS-PAS-SUS-11-010



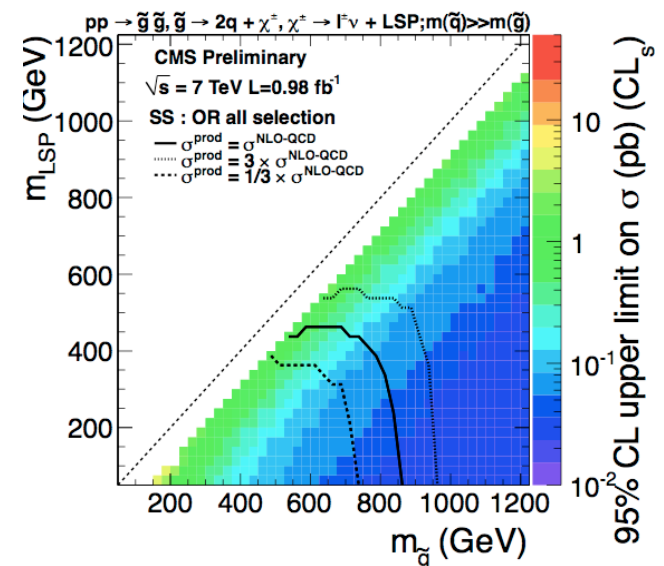
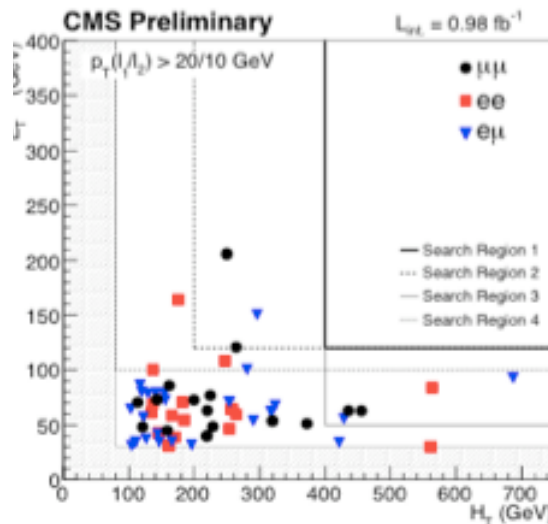
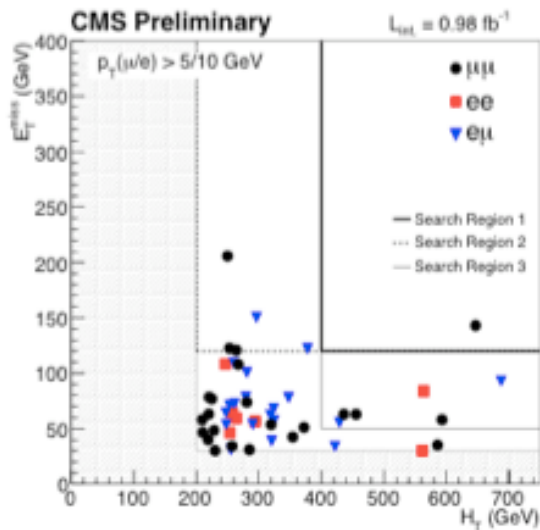
$$m(\tilde{\chi}^\pm, \tilde{\chi}_2^0) = \frac{m(\tilde{g}) + m(\tilde{\chi}_1^0)}{2}$$

A search for the SS dileptons profits from low SM background.

Best limit from high pt leptons

$\Delta M(\text{gluino}, \text{LSP}) > 300 \text{ GeV}$ from region $HT=400 \text{ MET}=120$

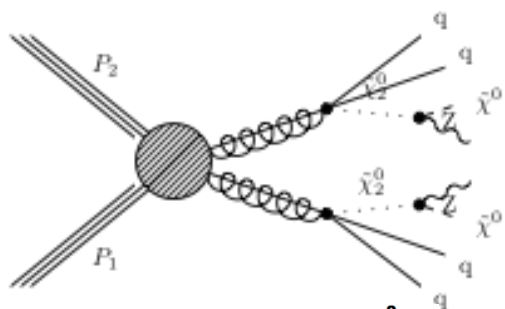
$\Delta M(\text{gluino}, \text{LSP}) < 300 \text{ GeV}$ from region $HT=200 \text{ MET}=120$



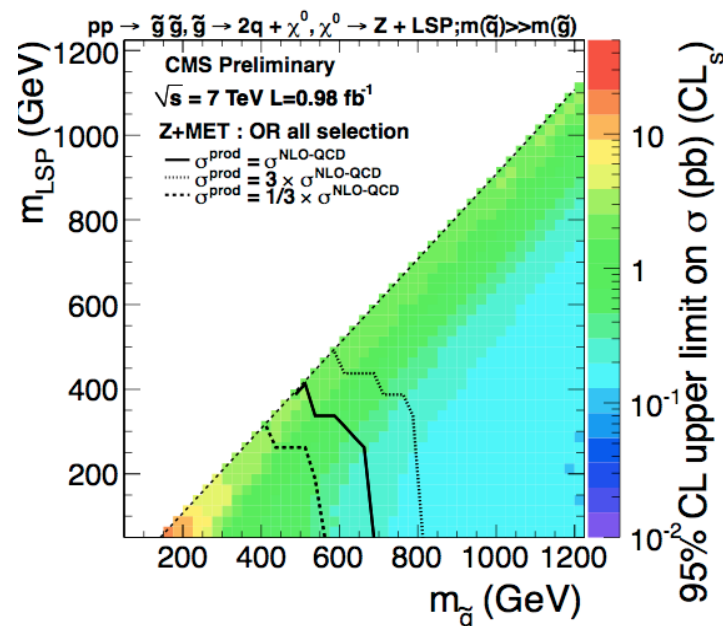
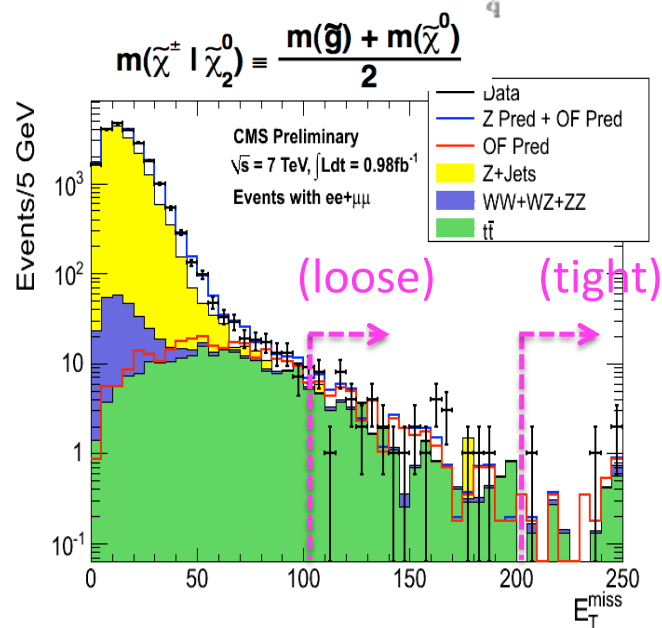
8/24/11

Limit on T5zz topology from Z analysis

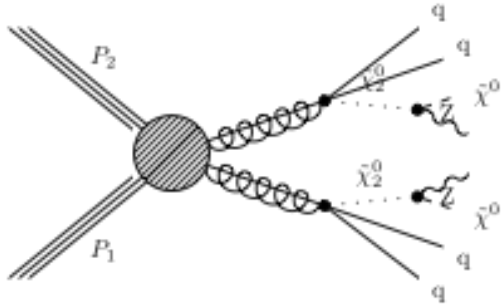
CMS-PAS-SUS-11-017



A search for the Z to leptons plots jets final state allows a low threshold on the jet activity requirements. Low gluino-LSP mass splitting can be probed with the loose met selection.



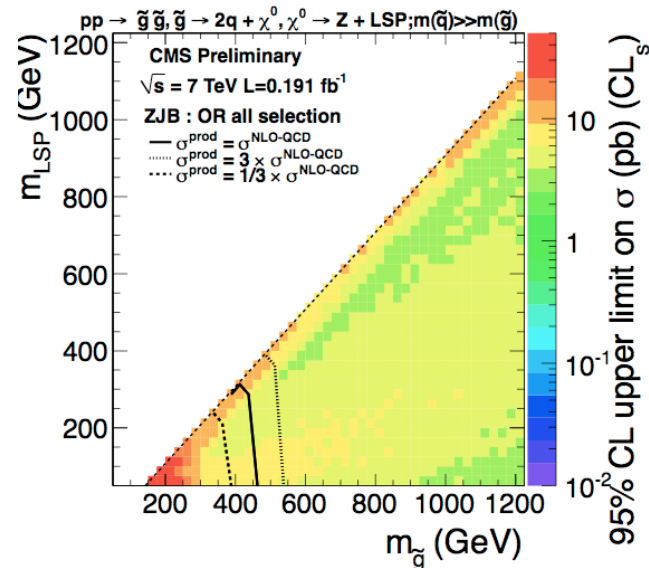
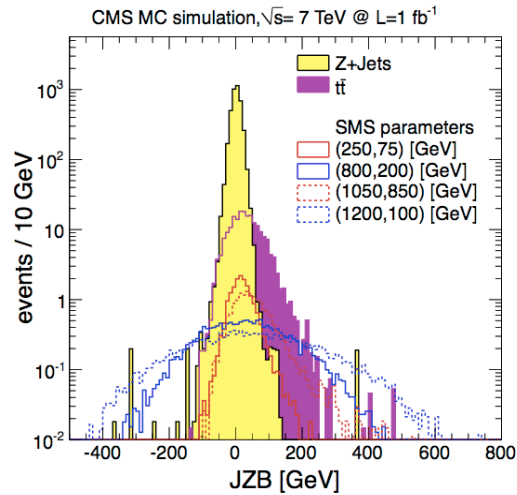
Limit on T5zz topology from Z analysis



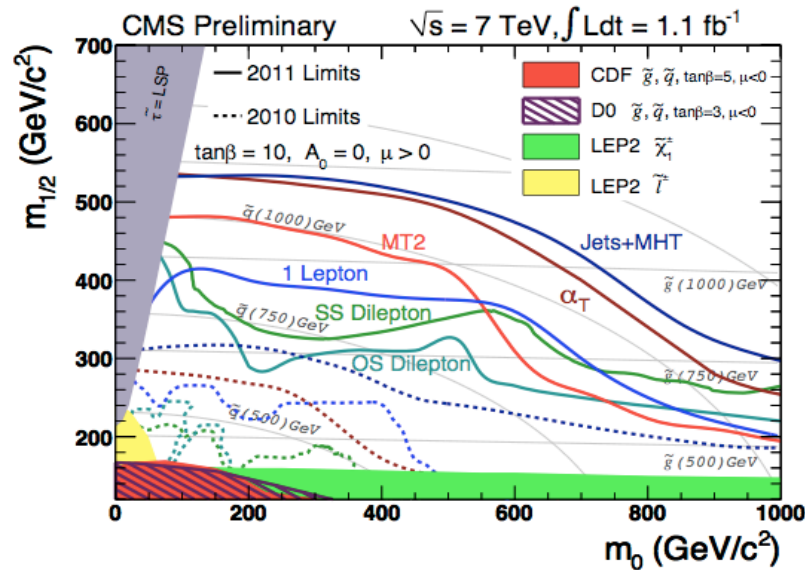
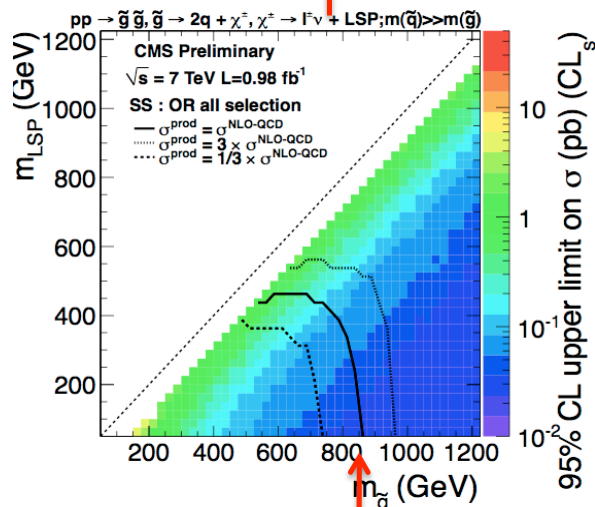
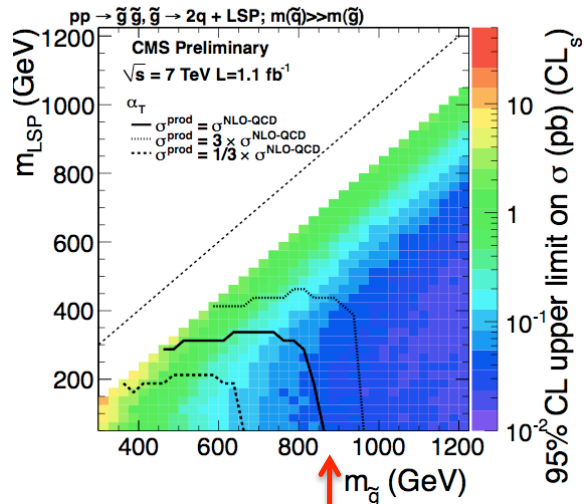
CMS-PAS-SUS-11-012

It is important to have different analyses looking at the same signature with orthogonal control sample for the background estimations.

$$JZB = \left| -\sum_{\text{jets}} \vec{p}_T \right| - \left| \vec{p}_T^{(Z)} \right| :$$



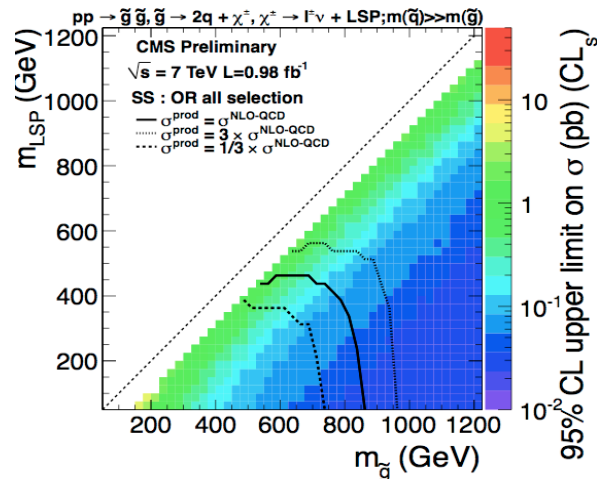
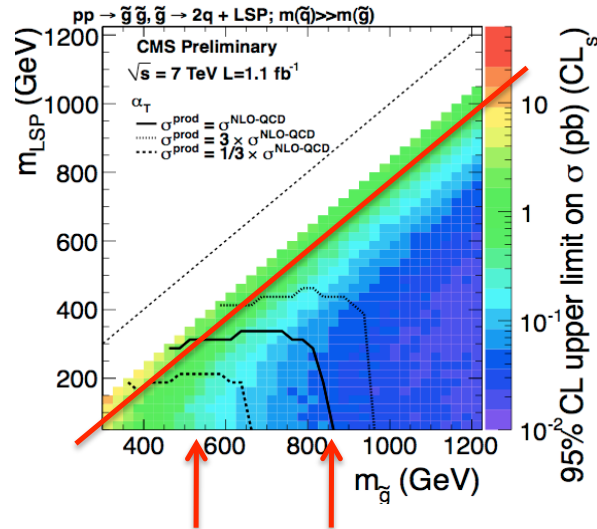
Summary



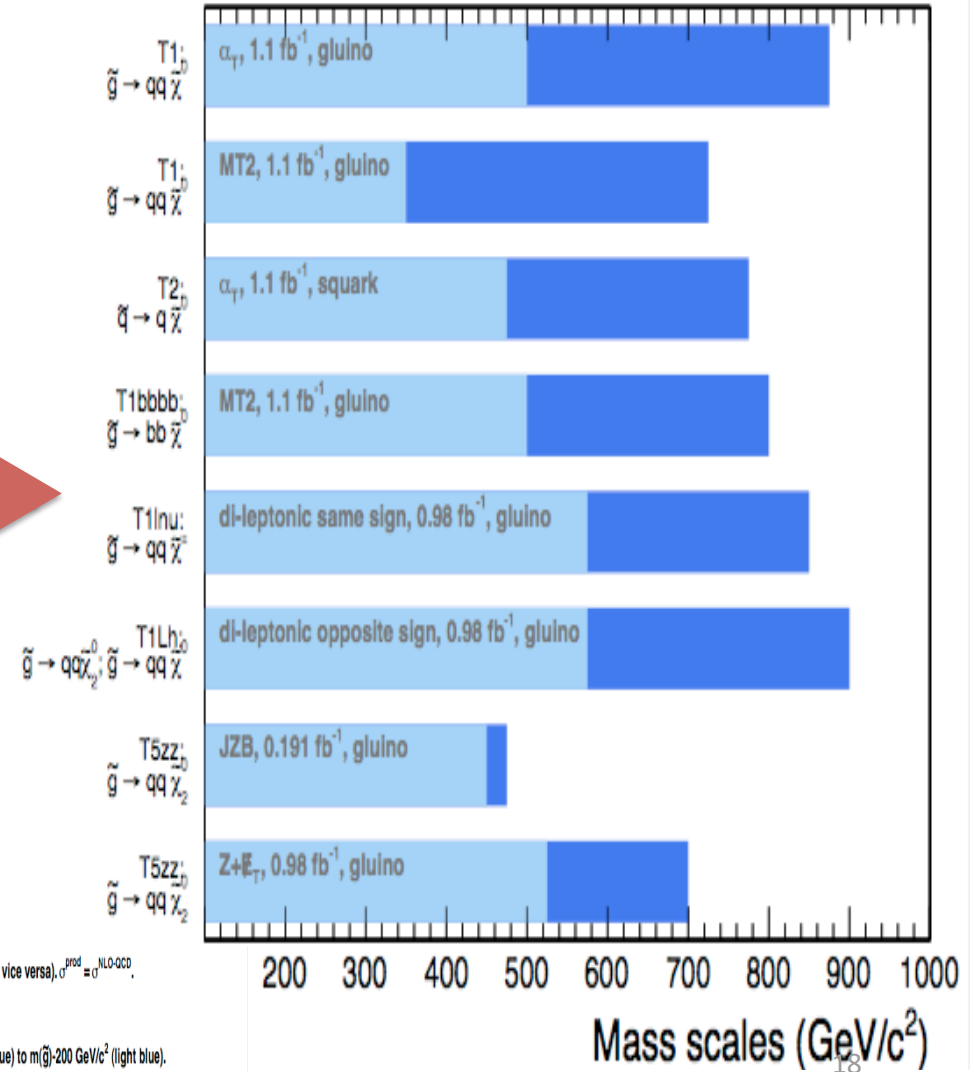
For models similar to the CMSSM (i.e. low LSP wrt gluino mass), the references exclusion limit is $\sim 800 \text{ GeV}$ in gluino mass ... but for more compressed spectra the picture changes to 500 GeV .

The SS dilepton analysis can more easily probe compressed spectra.

One plot summary



Ranges of exclusion limits for gluinos and squarks, varying $m(\tilde{\chi}^0)$
 CMS preliminary



For limits on $m(\tilde{g}), m(\tilde{q}) \gg m(\tilde{\chi}^0)$ (and vice versa), $\sigma^{\text{prod}} = \sigma^{\text{NLO-QCD}}$,
 $m(\tilde{\chi}^0), m(\tilde{\chi}_2^0) = \frac{m(\tilde{g}) + m(\tilde{\chi}^0)}{2}$,
 $m(\tilde{\chi}_2^0)$ is varied from 0 GeV/c² (dark blue) to $m(\tilde{g})$ -200 GeV/c² (light blue).

Prospective

Simplified models provide us with insight into the effects of kinematic extremes on the sensitivity of our analyses.

- A few topologies were already investigated after the first 35 pb⁻¹ in the context of the fully hadronic analysis (e.g. CMS-PAS-SUS-10-005)
- Here, additional models for the dileptons were presented.

More CMS analyses are foreseen to present soon their results in the context simplified models .

More simplified models will be added as well (for example associated production squark-gluino, longer decay chain, 3rd generation, photons, different mass splitting)

Stay tuned!

<http://www.bbc.co.uk/news/science-environment-14680570>

“Researchers failed to find evidence of so-called “supersymmetric” particles, which many physicists had hoped would plug holes in the current theory.”

... Not yet !

backup

Naming convention

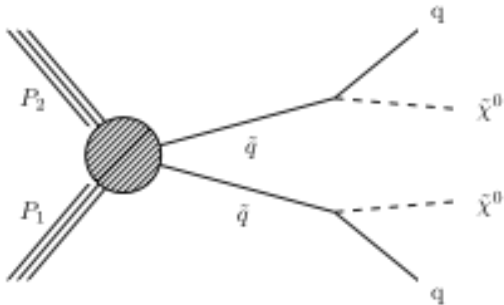
- A “constrained”, “fundamental”, or “full” model denotes a theory that is derived from first principles and defined at some arbitrary high-mass scale.
- A simplified model in contrast denotes a model that can – at least in principle – be formulated as an effective Lagrangian describing a small number of new particles and their interactions.
- A “**topology**” in this context refers to one specific set of production and decay mode, stopping usually with the standard model particles.
- Each topology can be mapped onto at least one detector “**signature**” – a set of well-defined physics objects – more than one if e.g. gauge bosons with both hadronic and leptonic decay modes appear in the model.
- An **analysis** is defined by its publication; each publication denotes exactly one analysis. An analysis is composed of one or more “searches” or “search strategies”.
- A “**search**” is defined as a specific set of trigger requirements, offline cuts, and background estimation techniques. A well-defined set of simplified models is sometimes also referred to as a “simplified model spectrum”.

Simplified Models Spectra (SMS)

Both experimental and theoretical considerations have influenced the selection of which simplified models are to be used for publications.

- On the experimental side, the analyses are categorized by the types and multiplicities of objects allowed in the final state, subject to kinematic and geometric cuts. The basic objects considered are jets, charged leptons, photons, and missing transverse momentum. The object types can be further refined to emphasize the third generation, e.g. b-jets and τ -leptons.
- From the theoretical side the following questions serve as a guidelines for the selection of simplified models:
 - What colored particle(s) dominate the production? Are they singly or pair-produced?
 - What is the mass hierarchy of the particle spectrum? Is there mass degeneracy?
 - Are W or Z bosons involved in the decay chains? Are they on- or off-shell?
 - Is the third generation (t, b or τ) to be singled out as special?
 - Is there a stable, neutral particle produced in the decay chain?

Limit on T2 topology



We use reference cross sections – for squark pair production in the limit of decoupled gluinos, and gluino pair production in the limit of decoupled squarks – calculated at next to leading order (NLO) precision using P R O S P I N O. These reference cross sections will be used to draw the 95 % exclusion contours on the cross section times branching fraction in the parameter space of the simplified models .

For the T2 topology the reference cross section is taken as the sum of the four light flavor.

The inverse problem

If evidence of a signal, likely there will be more than one interpretation more than more model . *SUSY*, *UED*, *Conformal Technicolor*, *Little Higgs*models etc.

The simplified model approach can be useful to guide the inverse process.

